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The effects of gear type on the Japanese squid (Illex illecebrosus) fishery

by

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Introduction

In July, August and September 1977, the R/V *Shirane Maru* was used for two trips which experimented with different gears in the Japanese squid fishery in ICNAF subdivision 4VWX. The vessel carried out regular fishing operations except that the gear type was changed periodically and fishing was concentrated in four predetermined areas. The object of the experiment was to determine if there was some combination of gear type and area that would allow adequate squid catches for a commercial operation and would also produce a minimal by-catch. The differences in catch rates between day and night fishing were also examined.

Equipment and Design

The three trawl gears used included two off-bottom gears and a regular otter trawl. One off-bottom gear had only dangler chains and will be referred to as the "chain" trawl. The other had dangler chains and large rollers or bobbins and will be referred to as the "bobbin" trawl. Details of the gear shapes and sizes are given in Table 1 and Figures 1 and 2. The mesh sizes were determined using a standard ICNAF measuring gauge.

During the two cruises, fishing was concentrated in 4 areas (Figs. 3&4). Areas 1, 2, and 4 were used during the first cruise. Areas 1, 2, and 3 were used during the second cruise. On the first cruise, the otter trawl gear was not used.

Results and experiences of the first cruise were used to help design the second cruise in such a way that the data obtained from it would be readily handled by standard statistical techniques. It was the aim of the second cruise to split the sets evenly between different gear types, between the different areas and proportionately between day and night. In each area it would have been ideal to randomly select the gear for each set but this was impossible due to the amount of time needed to change gear. Instead a fairly regular gear rotation was instituted.

On each set data was collected on the catch. The weights of squid and all by-catch species were measured or estimated. For each species, a sample of approximately 250 was taken to obtain length, weight, sex, maturity and ageing material.

Statistical Analysis

This analysis was only performed on the data from the second cruise. Tables 2 & 3 show the cross tabulations of area, gear and time in pairs. Area 0 is anything outside 1, 2 or 3. They show a uniform enough division of sampling to allow a meaningful standard analysis of variance to be run.

All data from the second cruise from areas 1, 2 and 3 was run through the SPSS ANOVA program (see Appendix 1.). To make the distributions more nearly normal ln (catch +1) was used instead of the raw catch data. A summary of the results is as follows:

Table 1. Dimensions of three trawling gear types.

GEAR NAME	CHAIN	REGULAR (OTTER)	BOBBIN
GEAR TYPE	PELAGIC	BOTTOM	BOTTOM
FOOT ROPE LENGTH (M)	60	72	72
HEAD ROPE LENGTH (M)	60	54	54
HEAD ROPE HEIGHT (M)	8	7	7
WINGSPREAD (M)	35	28	28
LENGTH OF BRIDLES (M)	150	173	173
TYPE OF DOORS	PELAGIC	BOTTOM	BOTTOM
DOOR WEIGHT (KG)	2100	3064	3064
DOOR LENGTH (CM)	220	260	260
DOOR HEIGHT (CM)	450	369	369
MESH SIZE IN WINGS (MM)	371	141	140
MESH SIZE IN BODY (MM)	143	114	113
MESH SIZE IN CODEND	91	92	93
LINER IN CODEND	YES	YES	YES
MESH SIZE IN LINER (MM)	45	44	43
CHAFING GEAR FITTED	YES	YES	YES
ROLLERS ON FOOTROPE	NO	YES	YES
CENTRAL ROLLER DIAMETER (MM)	0	0	530
LATERAL ROLLER DIAMETER (MM)	0	0	530

1. Squid. Only area is significant at the 5% level though gear and time are significant at the 10% level. No interactions are significant so the multiple classification analysis is meaningful. (This shows the mean of all observations and the deviations from the mean accounted for by different values of the independent variable). This shows that less squid was caught in area 3 and areas 1 and 2 are about equivalent. The otter trawl was most efficient and the chain least. 75% of the variation in catch is not accounted for by these variables.

2. Silver Hake. Gear and area were very significant but the two-way interactions between gear-area and area-time are also of borderline significance at the 10% level. These interaction terms indicate some bias in the multiple classification analysis and its results must be treated cautiously. Indications are that silver hake is caught predominately in area 2, and that chain gear will catch much less than the other two. Over half the variation in catch is explained.

3. Cod, Haddock, Plaice and Redfish. All other catches were small and the large number of zero catches may have affected the results since the distributions of ln (catch +1) did not closely approach normality. All ANOVA's showed

significant interactions at the 1% level and thus the multiple classification analyses must be treated with some skepticism. However, on the whole the otter trawl caught the most and the chain caught almost none. For area, the results are more variable. More haddock was caught in area 3 where the least plaice and redfish were caught. For cod, area was not significant.

Table 2. Japanese squid data, Jan. 1978, cross tabulations of gear, area and time.

GEAR	COUNT	AREA 0	1	2	3	ROW TOTAL
OTTER	1	3	14	12	14	43 33.1
CHAIN	2	0	15	16	13	44 33.8
BOBBIN	3	2	13	15	13	43 33.1
COLUMN TOTAL		5 3.8	42 32.3	43 33.1	40 30.8	130 100.0

GEAR	COUNT	TIME DAY 1	NIGHT 2	ROW TOTAL
OTTER	1	31	12	43 33.1
CHAIN	2	33	11	44 33.8
BOBBIN	3	32	11	43 33.1
COLUMN TOTAL		96 73.8	34 26.2	130 100.0

There was one major problem with the analysis. The areas were fished in the other 1, then 2, then 3. Some of the inter-area differences may be due to date and not area. Two tests were used to try and help resolve this problem. The longest data series exists for area 1 because it was most heavily used on the first trip. Regressions were run of ln (catch +1) vs. date and $(\text{date})^2$ for all area 1 catches and for bobbin and chain catches, each separately. In all the runs very little of the variation was explained, and for any coefficient of date or $(\text{date})^2$ that showed significance, zero was always in the 95% confidence interval for that coefficient. However, this analysis did not cover the whole time of the second cruise. The second test was to run date as a covariate in the ANOVA's discussed above. The results were ambiguous. There was no increase in amount of variance explained but some of the significance of the area parameter was reduced. See the following table:

Area listed according to positive affect on catch, highest first

	Without date variable	After adjusting for date
Squid	1) about	2) about
	2) equal	1) equal
	3	3
Silver Hake	2	2
	1	3
	3	1

For squid the effect is small, since area 1 and 2 do not differ significantly. For silver hake the difference is marked. The true effect of date must lie somewhere between these extremes but the data does not allow a complete analysis since the effect is confounded with the effect due to area.

The analysis shows that chain gear catches somewhat less squid but catches much less by-catch. It also shows that more squid can be taken in areas 1 and 2 than in 3. If date is significant, the least is caught in area 1. The difference is significant and if the decision on which area produces least by-catch is used to determine where to fish squid, it will significantly affect the squid catch. However, the way the data was collected does not permit an analysis that would settle this question.

Table 3. Japanese squid data, Jan. 1978. cross tabulations of gear, area and time.

AREA	COUNT	TIME: DAY 1	NIGHT 2	ROW TOTAL
	0	5	0	5
				3.8
	1	32	10	42
				32.3
	2	30	13	43
				33.1
	3	29	11	40
				30.8
	COLUMN TOTAL	96	34	130
		73.8	26.2	100.0

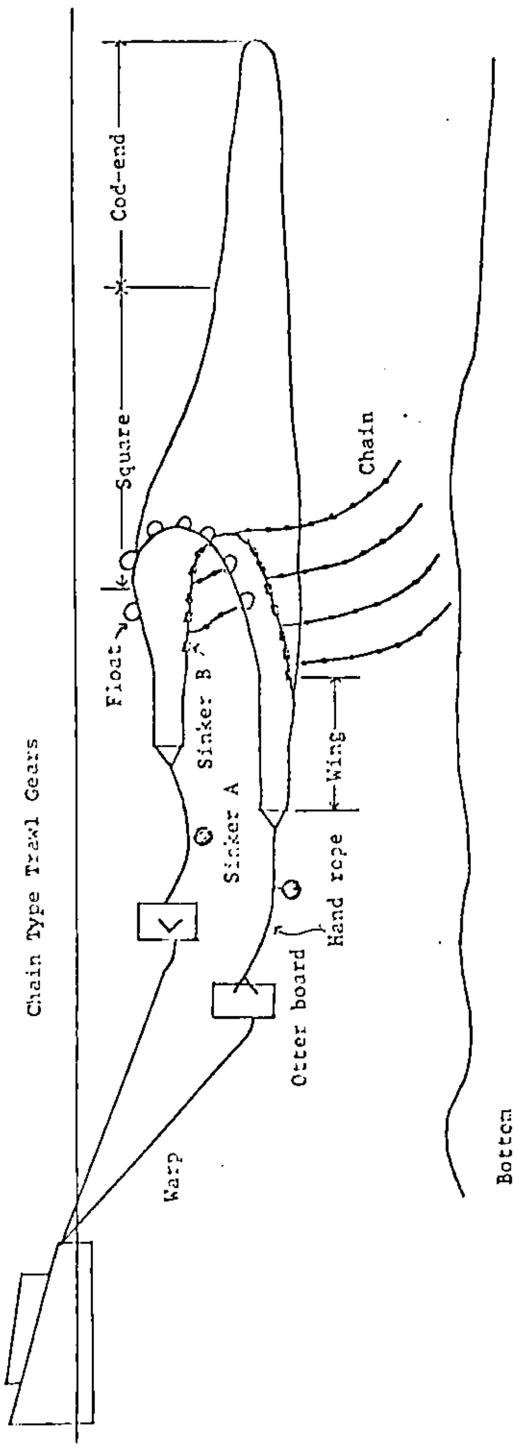

FIG. 1. CHAIN TYPE TRAWL.

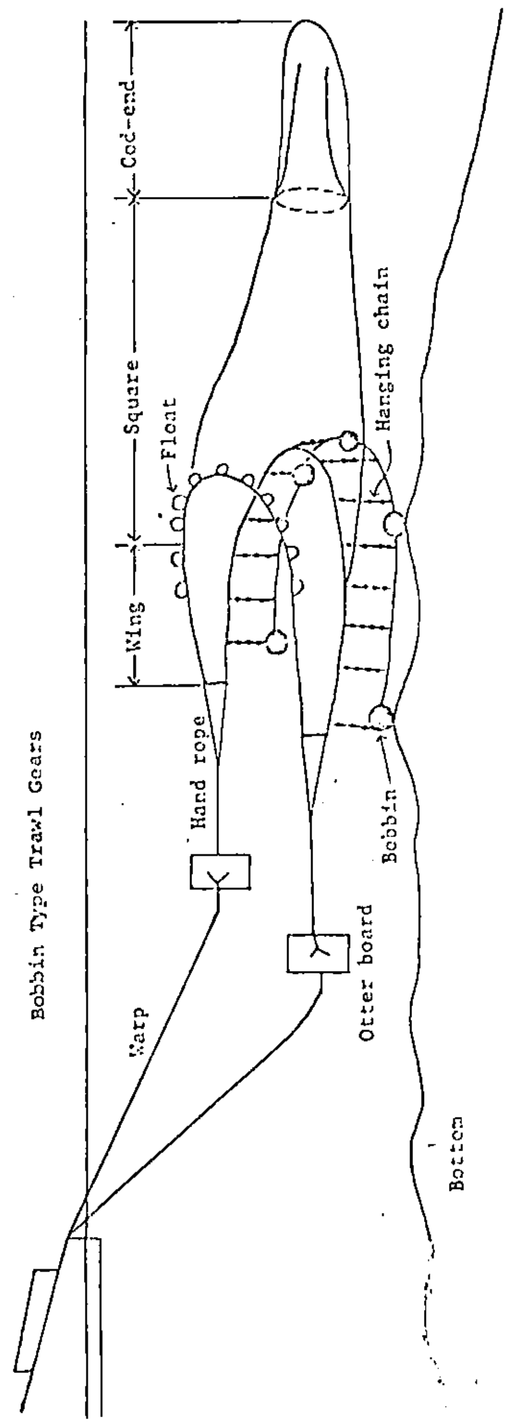

FIG. 2. BOBBIN TYPE TRAWL

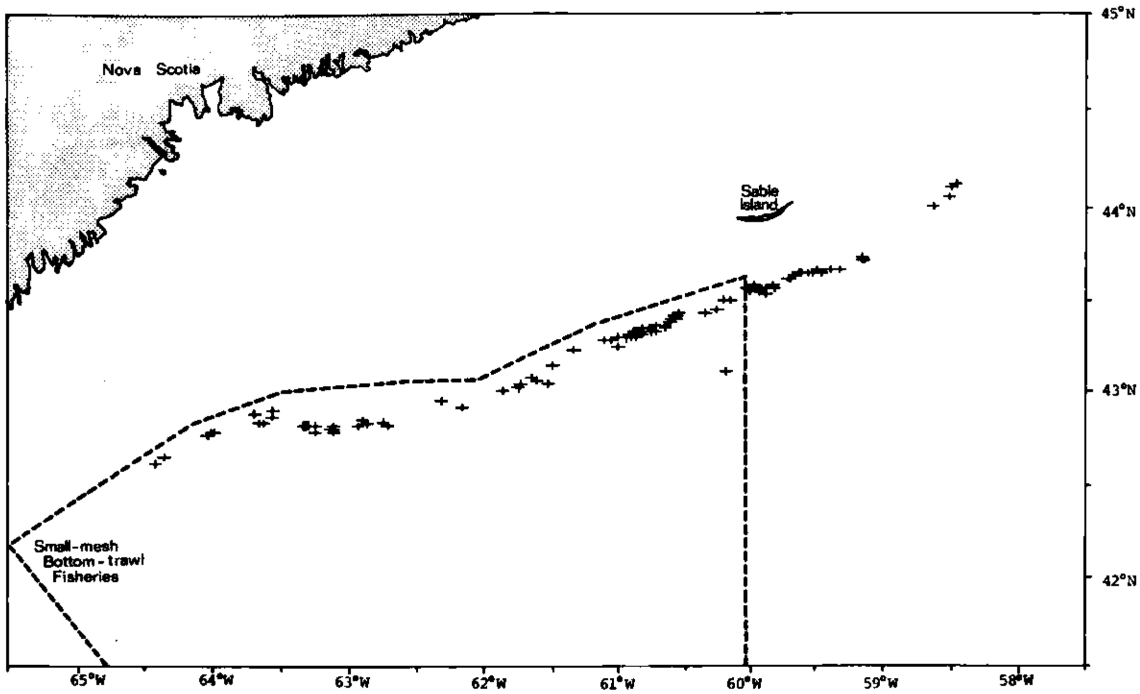

Fig. 3. Sampling locations for Phase I of the 1977 Canada-Japan gear study.

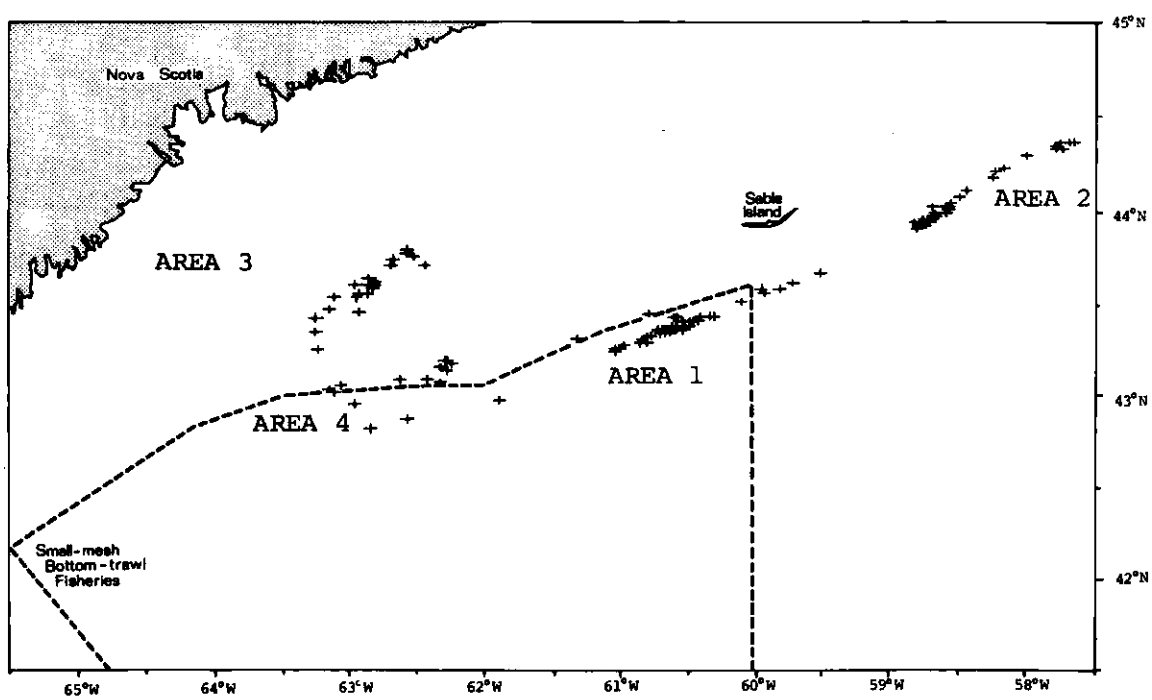

Fig. 4. Sampling locations for Phase II of the 1977 Canada-Japan gear study.

JAPANESE SQUID DATA, JAN. 1978
ANALYSIS OF VARIANCE; SIX SPECIES, CLASSICAL ON LN + 1
FILE NONAME (CREATION DATE = 78/03/03.)

* * * * * * * * * * A N A L Y S I S   O F   V A R I A N C E * * * * * * * * * *

SQUID
BY GEAR
AREA
TIME

* *

SOURCE OF VARIATION	SUM OF SQUARES	DF	MEAN SQUARE	F	SIGNIF OF F
MAIN EFFECTS	213.458	5	42.692	7.468	.001
GEAR	26.524	2	13.262	2.320	.103
AREA	177.522	2	88.761	15.527	.001
TIME	15.860	1	15.860	2.774	.099
2-WAY INTERACTIONS	25.975	8	3.247	.568	.802
GEAR AREA	18.564	4	4.641	.812	.520
GEAR TIME	4.046	2	2.023	.354	.703
AREA TIME	1.132	2	.566	.099	.906
3-WAY INTERACTIONS	2.997	4	.749	.131	.971
GEAR AREA TIME	2.997	4	.749	.131	.971
EXPLAINED	242.430	17	14.261	2.495	.002
RESIDUAL	611.677	107	5.717		
TOTAL	854.107	124	6.888		

* * *   M U L T I P L E   C L A S S I F I C A T I O N   A N A L Y S I S   * * *

SQUID
BY GEAR
AREA
TIME

* *

GRAND MEAN = 6.11

VARIABLE + CATEGORY	N	UNADJUSTED DEV'N	ETA	ADJUSTED FOR INDEPENDENTS DEV'N	BETA	ADJUSTED FOR INDEPENDENTS + COVARIATES DEV'N	BETA
GEAR							
1 OTTER	40	.37		.47			
2 CHAIN	44	-.53		-.61			
3 BOBBIN	41	.20		.19			
			.15		.18		
AREA							
1	42	.89		.87			
2	43	.72		.77			
3	40	-1.71		-1.74			
			.45		.46		
TIME							
1 DAY	91	.21		.22			
2 NIGHT	34	-.57		-.58			
			.13		.14		
MULTIPLE R SQUARED					.250		
MULTIPLE R					.500		

JAPANESE SQUID DATA, JAN. 1978
ANALYSIS OF VARIANCE; SIX SPECIES, CLASSICAL ON LN + 1
FILE NONAME (CREATION DATE = 78/03/03.)

* * * * * * * * * * * A N A L Y S I S O F V A R I A N C E * * * * * * * * * * *

SILHAKE
BY GEAR
AREA
TIME

* *

SOURCE OF VARIATION	SUM OF SQUARES	DF	MEAN SQUARE	F	SIGNIF OF F
MAIN EFFECTS	321.023	5	64.205	33.639	.001
GEAR	144.806	2	72.403	37.934	.001
AREA	182.893	2	91.447	47.912	.001
TIME	2.269	1	2.269	1.189	.278
2-WAY INTERACTIONS	29.244	8	3.655	1.915	.065
GEAR AREA	14.999	4	3.750	1.965	.105
GEAR TIME	4.401	2	2.201	1.153	.320
AREA TIME	9.330	2	4.665	2.444	.092
3-WAY INTERACTIONS	4.698	4	1.174	.615	.653
GEAR AREA TIME	4.698	4	1.174	.615	.653
EXPLAINED	354.965	17	20.880	10.940	.001
RESIDUAL	204.224	107	1.909		
TOTAL	559.190	124	4.510		

* * * M U L T I P L E C L A S S I F I C A T I O N A N A L Y S I S * * *

SILHAKE
BY GEAR
AREA
TIME

* *

GRAND MEAN = 2.81

VARIABLE + CATEGORY	N	UNADJUSTED DEV'N	ETA	ADJUSTED FOR INDEPENDENTS DEV'N	BETA	ADJUSTED FOR INDEPENDENTS + COVARIATES DEV'N	BETA
GEAR							
1 OTTER	40	.71		.81			
2 CHAIN	44	-1.40		-1.46			
3 BOBBIN	41	.81		.77			
			.49		.51		
AREA							
1	42	-.22		-.19			
2	43	1.49		1.52			
3	40	-1.37		-1.43			
			.56		.57		
TIME							
1 DAY	91	-.13		-.08			
2 NIGHT	34	.35		.22			
			.10		.06		
MULTIPLE R SQUARED					.574		
MULTIPLE R					.758		

JAPANESE SQUID DATA, JAN. 1978
ANALYSIS OF VARIANCE; SIX SPECIES, CLASSICAL ON LN + 1
FILE NONAME (CREATION DATE = 78/03/03.)

* * * * * * * * * * * A N A L Y S I S O F V A R I A N C E * * * * * * * * * * *

COD
BY GEAR
AREA
TIME

SOURCE OF VARIATION	SUM OF SQUARES	DF	MEAN SQUARE	F	SIGNIF OF F
MAIN EFFECTS	13.682	5	2.736	5.011	.001
GEAR	11.805	2	5.902	10.809	.001
AREA	1.357	2	.678	1.243	.293
TIME	.244	1	.244	.447	.505
2-WAY INTERACTIONS	3.892	8	.487	.891	.527
GEAR AREA	1.613	4	.403	.738	.568
GEAR TIME	.482	2	.241	.442	.644
AREA TIME	2.020	2	1.010	1.849	.162
3-WAY INTERACTIONS	7.454	4	1.864	3.413	.011
GEAR AREA TIME	7.454	4	1.864	3.413	.011
EXPLAINED	25.029	17	1.472	2.696	.001
RESIDUAL	58.428	107	.546		
TOTAL	83.457	124	.673		

* * * M U L T I P L E C L A S S I F I C A T I O N A N A L Y S I S * * *

COD
BY GEAR
AREA
TIME

GRAND MEAN = .33

VARIABLE + CATEGORY	N	UNADJUSTED DEV'N	ETA	ADJUSTED FOR INDEPENDENTS DEV'N	BETA	ADJUSTED FOR INDEPENDENTS + COVARIATES DEV'N	BETA
GEAR							
1 OTTER	40	.42		.42			
2 CHAIN	44	-.33		-.33			
3 BOBBIN	41	-.05		-.06			
			.38		.38		
AREA							
1	42	-.14		-.15			
2	43	.03		.06			
3	40	.11		.09			
			.13		.13		
TIME							
1 DAY	91	-.04		-.03			
2 NIGHT	34	.10		.07			
			.08		.05		
MULTIPLE R SQUARED					.164		
MULTIPLE R					.405		

JAPANESE SQUID DATA, JAN. 1978
ANALYSIS OF VARIANCE; SIX SPECIES, CLASSICAL ON LN + 1
FILE NONAME (CREATION DATE = 78/03/03.)

* * * * * * * * * * A N A L Y S I S O F V A R I A N C E * * * * * * * * * *
HADDOCK
BY GEAR
AREA
TIME
* *

SOURCE OF VARIATION	SUM OF SQUARES	DF	MEAN SQUARE	F	SIGNIF OF F
MAIN EFFECTS	78.503	5	15.701	11.637	.001
GEAR	34.741	2	17.371	12.875	.001
AREA	41.709	2	20.854	15.457	.001
TIME	.039	1	.039	.029	.865
2-WAY INTERACTIONS	29.800	8	3.725	2.761	.008
GEAR AREA	22.935	4	5.734	4.250	.003
GEAR TIME	.991	2	.495	.367	.694
AREA TIME	5.342	2	2.671	1.980	.143
3-WAY INTERACTIONS	37.031	4	9.258	6.862	.001
GEAR AREA TIME	37.031	4	9.258	6.862	.001
EXPLAINED	145.335	17	8.549	6.336	.001
RESIDUAL	144.364	107	1.349		
TOTAL	289.699	124	2.336		

* * * M U L T I P L E C L A S S I F I C A T I O N A N A L Y S I S * * *
HADDOCK
BY GEAR
AREA
TIME
* *

GRAND MEAN = .72

VARIABLE + CATEGORY	N	UNADJUSTED DEV'N	UNADJUSTED ETA	ADJUSTED FOR INDEPENDENTS DEV'N	ADJUSTED FOR INDEPENDENTS BETA	ADJUSTED FOR INDEPENDENTS + COVARIATES DEV'N	ADJUSTED FOR INDEPENDENTS + COVARIATES BETA
GEAR							
1 OTTER	40	.51		.50			
2 CHAIN	44	-.72		-.70			
3 BOBBIN	41	.28		.26			
			.36		.35		
AREA							
1	42	-.71		-.71			
2	43	-.01		.02			
3	40	.75		.72			
			.39		.38		
TIME							
1 DAY	91	-.01		.01			
2 NIGHT	34	.04		-.03			
			.02		.01		
MULTIPLE R SQUARED					.271		
MULTIPLE R					.521		

JAPANESE SQUID DATA, JAN. 1978
ANALYSIS OF VARIANCE; SIX SPECIES, CLASSICAL ON LN + 1
FILE NONAME (CREATION DATE = 78/03/03.)

* * * * * * * * * * A N A L Y S I S O F V A R I A N C E * * * * * * * * * *

PLAICE
BY GEAR
AREA
TIME

* *

SOURCE OF VARIATION	SUM OF SQUARES	DF	MEAN SQUARE	F	SIGNIF OF F
MAIN EFFECTS	66.123	5	13.225	20.195	.001
GEAR	55.456	2	27.728	42.343	.001
AREA	10.413	2	5.207	7.951	.001
TIME	1.503	1	1.503	2.295	.133
2-WAY INTERACTIONS	12.694	8	1.587	2.423	.019
GEAR AREA	9.346	4	2.337	3.568	.009
GEAR TIME	3.175	2	1.588	2.425	.093
AREA TIME	.440	2	.220	.336	.716
3-WAY INTERACTIONS	2.608	4	.652	.996	.413
GEAR AREA TIME	2.608	4	.652	.996	.413
EXPLAINED	81.426	17	4.790	7.314	.001
RESIDUAL	70.068	107	.655		
TOTAL	151.494	124	1.222		

* * * M U L T I P L E C L A S S I F I C A T I O N A N A L Y S I S * * *

PLAICE
BY GEAR
AREA
TIME

* *

GRAND MEAN = .85

VARIABLE + CATEGORY	N	UNADJUSTED DEV'N	ETA	ADJUSTED FOR INDEPENDENTS DEV'N	BETA	ADJUSTED FOR INDEPENDENTS + COVARIATES DEV'N	BETA
GEAR							
1 OTTER	40	.73		.75			
2 CHAIN	44	-.84		-.85			
3 BOBBIN	41	.19		.19			
			.60		.61		
AREA							
1	42	.13		.14			
2	43	.22		.25			
3	40	-.37		-.42			
			.23		.26		
TIME							
1 DAY	91	-.09		-.07			
2 NIGHT	34	.23		.18			
			.13		.10		
MULTIPLE R SQUARED					.436		
MULTIPLE R					.661		

JAPANESE SQUID DATA, JAN. 1978
ANALYSIS OF VARIANCE; SIX SPECIES, CLASSICAL ON LN + 1
FILE NONAME (CREATION DATE = 78/03/03.)

* * * * * * * * * * A N A L Y S I S O F V A R I A N C E * * * * * * * * * *

REDFISH
BY GEAR
AREA
TIME

* *

SOURCE OF VARIATION	SUM OF SQUARES	DF	MEAN SQUARE	F	SIGNIF OF F
MAIN EFFECTS	28.201	5	5.640	8.078	.001
GEAR	4.780	2	2.390	3.423	.036
AREA	19.657	2	9.829	14.077	.001
TIME	2.911	1	2.911	4.169	.044
2-WAY INTERACTIONS	17.847	8	2.231	3.195	.003
GEAR AREA	4.825	4	1.206	1.726	.149
GEAR TIME	5.707	2	2.854	4.087	.019
AREA TIME	8.385	2	4.193	6.005	.003
3-WAY INTERACTIONS	9.268	4	2.317	3.319	.013
GEAR AREA TIME	9.268	4	2.317	3.319	.013
EXPLAINED	55.316	17	3.254	4.660	.001
RESIDUAL	74.709	107	.698		
TOTAL	130.026	124	1.049		

* * * M U L T I P L E C L A S S I F I C A T I O N A N A L Y S I S * * *

REDFISH
BY GEAR
AREA
TIME

* *

GRAND MEAN = .36

VARIABLE + CATEGORY	N	UNADJUSTED DEV'N	UNADJUSTED ETA	ADJUSTED FOR INDEPENDENTS DEV'N	ADJUSTED FOR INDEPENDENTS BETA	ADJUSTED FOR INDEPENDENTS + COVARIATES DEV'N	ADJUSTED FOR INDEPENDENTS + COVARIATES BETA
GEAR							
1 OTTER	40	.02		.05			
2 CHAIN	44	-.24		-.25			
3 BOBBIN	41	.24		.22			
			.19		.19		
AREA							
1	42	-.28		-.26			
2	43	.56		.55			
3	40	-.31		-.32			
			.40		.39		
TIME							
1 DAY	91	-.11		-.09			
2 NIGHT	34	.29		.25			
			.17		.15		

MULTIPLE R SQUARED .217
MULTIPLE R .466